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Studies on impact of stingless bee (*Tetragonula iridipennis*) pollination in watermelon (*Citrullus lanatus*)

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Abstract
A field experiment was conducted to study the impact of stingless bee (*Tetragonula iridipennis*) pollination on watermelon. The study was conducted in RBD with 3 replications and 7 treatments i.e., T1-caged with stingless bee, T2-Caged with hand pollination, T3-caged with stingless bee +hand pollination, T4-open pollination + hand pollination, T5-open pollination, T6-open pollination+ sugar solution spray (30%), T7-control. The incidence of different pollinators were recorded. The pollination efficiency index was calculated using different foraging and quality parameters. The highest fruit weight (2.38 kg) was recorded in stingless bee plots and the lowest weight was recorded in control plot (0.95 kg). Similarly, higher fruit set (58.55%), healthy fruit (65.58%) and lower deformed fruit (11.89%) were recorded in stingless bee pollinated treatment over control (16.52%).

Keywords: Stingless bee, *Citrullus lanatus*, pollination, foraging activity, fruit set, diversity index

Introduction

Pollination play a crucial role in the functioning of the ecosystem which support food production, natural resources and habitat. The pollinators have a major and increasing role in the process of food production. Over the last few decades, the production of pollinator dependant crops have increased threefold. For pollination services, insects act as a main pollinating vector. An estimate of about 30% of the human food is derived from bee-pollinated crops. In the world there are more number of honey bees than any other type of bees and pollinating insects. *Apis cerana, Apis dorsata, Apis florea* and *Tetragonula iridipennis* (stingless bees) are other important pollinators found all over the world (Zych *et al*., 2013) [16]. However, stingless bee can also be used as an effective pollinator for a wide range of crops. Several studies have proven stingless bee to be a potential agent and also act as a future alternative for commercial crop production.

Watermelon is a cross pollinated plant and is dependent on pollinators for fruit set (Walter, 2005) [14]. *Apis mellifera* is considered to be the most important pollinator for watermelon that are grown commercially (Stanghellini *et al*., 1997) [13]. Besides *Apis mellifera* different researchers have also tested other pollinators for pollination in watermelon. Stingless bee (*Tetragonula iridepennis*) as a pollinator and its utilisation and management for pollination is least studied and very few researchers have utilised this bee species as a pollinator for crop pollination (Kishan *et al*., 2017; Chauhan and Singh, 2021) [8, 5]. Stingless bee can be used as an alternative to commercialized honeybee pollinators for pollination of crops. These bees have proven to be superior as a pollinating agent due to several characteristics which include, ability to pollinate small flowers, flourish much better in tropical areas, harmless to humans, more environmental friendly, fidelity and constancy etc. (Chauhan and Singh, 2021) [5]. There are several other features which makes stingless be very adequate for pollination besides the fact that many species of stingless bee (*Tetragonula iridipennis*, *L. Ventralis*) can be managed in hives (Chauhan and Singh, 2020). Stingless bee have proved to forage well in greenhouse and even under adverse climatic conditions round the year. This particular property enables them to be a effective pollinator during odd season production of crops. Different researchers reported the abundance of stingless bees on different crops like cucumber, watermelon, litchi, citrus, ash gourd and tomato (Chauhan and Singh, 2019; 2021; Chauhan *et al*., 2020; Campbell *et al*., 2019; Bomfim *et al*., 2014; Malar, 2020) [4, 5, 3, 2]. The North Eastern Region has a lot of potential in beekeeping due to its richness in flora. In particular, Nagaland is considered to be home for varieties of honey bee (*Apis* sp.) and stingless bee (*Tetragonula* spp. and *Lepidotrigona* spp.) and hence there is large scope in beekeeping (Chauhan and Singh, 2021) [5]. Thus, considering all the potential of stingless bee, the present study was conducted and the results were evaluated.

Materials and Methods

The experiment was carried out in the experimental farm, Department of Entomology, School of Agricultural Sciences and Rural Development, Medziphema. The experimental site is located at 23º45'53" N latitude and 93 ºC 52'04" longtitude at an elevation of 310 metres above Mean Sea Level. The experiment was carried out in an open field and semi-open field condition. The crop was raised as per good agricultural practices and proper agronomical practices were followed. The different insects visiting the watermelon flowers were observed visually during the experiment. Hives of stingless bee (*Tetragonula iridipennis*) was introduced at 5-10% flowering stage. The diversity of pollinator was calculated using Shanon-Weiner diversity index formula. Similarly, pollination efficiency index was also calculated out using the formula as suggested by Bohart and Nye (1960) and Chauhan *et al*. (2019) [4].

Pollination efficiency = RA (FR+FS+LPG)

Where,
RA = Relative abundance.
FR = Foraging rate.
FS = Foraging speed.
LPG = Loose pollen grains.

The impact of different modes of pollination on watermelon was evaluated using different parameters. For each parameter, ten plants from each treatment were selected and tagged. The fruit set on the selected plants were recorded and total yield was also calculated out based on the data recorded. In the same way percent healthy and crooked/deformed/malformed fruits were also calculated out by counting the number of defective fruits from total fruit set. The data for fruit diameter and fruit weight was deliberated out by using digital vernier calliper and digital weighing balance from a sample of 10 fruits selected from each treatment and fruit TSS (%) was calculated out using refractometer. For counting the number of seeds per fruit, a sample of 10 fruits from each treatment were selected. The seeds were then washed and dried by keeping them in temperature-controlled chamber for 24 hours and counted. One thousand dried seeds from each treatment were taken separately in a petriplate and weighed using weighing balance. The percent increase in fruit set, healthy fruits, reduction in deformed fruits, number of seeds, weight of 1000 seeds was also calculated out. The data recorded on various parameters were statistically analysed with suitable transformation in RBD designed by Gomez and Gomez (1984).

Results and discussion

Different pollinators and insect visitors were recorded out of which *T. iridipennis*, *A. mellifera*, *A. cerana*, *Lophotrigona canifrons*, *Lepitotrigona ventralis* Smith were recorded to be the most frequent visitor followed by *Tetragonula laeviceps*, *Xylocapa tenuiscapa*, *Xylocapa fenestrate*, *Halictus semiaerinus* to be the frequent visitor and *Musca* sp as the least frequent visitor. Layek *et al*. (2020) also reported that Hymenopterans were the most frequent visitor in watermelon crop under open-pollination system. Walter and Schultheis (2009) [15] also documented that 85% of the pollinators and watermelon crop comprised of honeybees. Njoroge (2004) [11] also reported *A. mellifera* to be the main pollinator on watermelon. Chauhan and Singh (2021) [5] recorded different pollinators on watermelon crop viz. *T. iridepennis*, *T. laeviceps*, *A. mellifera*, *A. cerana*, *H. semiaerinus*, *Musca* sp where *T. iridepennis* was recorded to be the most frequent visitor.

Observations recorded on the relative abundance, foraging rate, foraging speed as represented in table 1 revealed that *T. iridipennis* (4.42) was the most abundant insect visitor on watermelon crop followed by *A. mellifera* (4.15) and *T. laeviceps* (3.97). The foraging activities of different pollinators initiated at 0600 h and the maximum activity was recorded at 0800-1000 h respectively. Similarly, the foraging activity of *T. iridipennis* started at 0600 h, their peak activity was recorded at 0800-1000 h and cessation time at 1630 h. Sawatthum (2017) [12] also reported that foraging activities of stingless bee start much earlier at 0600 h and continued upto 1800 h. Chauhan and Singh, 2021 [5] also observed that the activity of different pollinators on watermelon crop started at 0600 h with its maximum activity at 1000 h and started decreasing by 1600 h and was minimum at 1800 h. Pollination efficiency index was also recorded to be highest incase of *T. iridipennis* (18) (Table 2) followed by *A. mellifera* (14) and *T. laeviceps* (5). Likewise, Chauhan and Singh, 2021 [5] also reported maximum pollination efficiency index with stingless bee (21.00) as compared to honey bees (16.00) and other pollinators (3.00). The highest fruit set was recorded in T1 (58.5%), followed by T3 (53.37%), T6 (48.51%), T5 (44.72%), T4 (40.84%), T2 (38.66%) and T7 (35.84%) (Table 3). Likewise, the highest healthy fruit (65.58%) and less deformed fruits (11.89%) was recorded in T1. The highest fruit length (20.6 cm) with a fruit diameter of (17.3 cm), fruit weight (2.38 kg), TSS (9.3%) and rind thickness (1.7 cm) was recorded in T1 over T7 i.e., control which recorded fruit length (13.0 cm), fruit diameter (10.5 cm), fruit weight (0.95 kg), TSS (7.1%) and rind thickness (1.1 cm). Layek *et al*., (2020) studied the impact of stingless bee pollination on different yield parameters and reported higher fruit set (78%) in open pollination in stingless bee as compared to 64% in open pollination. They also reported that the fruit set have increased by 14% after the introduction of stingless bees. Chauhan and Singh, 2021 [5] have also reported higher % of fruit set and healthy fruit in stingless bee pollinated plot over control. Mitta *et al*., 2017 also reported increase in fruit length (19.1 cm), fruit girth (6.5 cm) and fruit weight (119.0 g) in stingless bee pollinated plots as compared to fruit length (17.6 cm), fruit girth (10.7 cm) and fruit weight (113.7 g) in control plot in cucumber crop. A study on pollination efficiency of stingless bee was conducted by Azmi *et al*., 2016 and recorded higher number of seeds (112.54 seeds/fruit) in stingless bee pollinated treatment as compared to hand pollinated treatment (102.92 seeds/fruit) treatments in chilli crop Cruz *et al*., 2005 documented higher number of seeds per fruit (137.83 seeds) in stingless bee pollinated treatments as compared to hand pollination (126.52 seeds). Hosamani *et al*., 2020 [7] also studied the effect of bee pollination and attractants on qualitative and quantitative parameters and reported a higher number of seeds per fruit in bee pollinated treatments over control in onion.

Table 1: Foraging activity and pollination efficiency index of pollinators on watermelon

	Tetragonula iridipennis				*Apis mellifera*				*Tetragonula laeviceps*			
Time (h)	**Relative abundance**	**Foraging rate**	**Foraging speed**	**Loose pollen grains**	**Relative abundance**	**Foraging rate**	**Foraging speed**	**Loose pollen grains**	**Relative abundance**	**Foraging rate**	**Foraging speed**	**Loose pollen grains**
0600	3.93	7.62	6.34	1618	3.88	7.21	6.21	2015	3.55	7.09	5.83	1405
0800	5.96	9.86	6.24		5.39	9.26	5.98		5.21	8.20	5.32	
1000	4.81	8.54	5.82		4.67	8.17	5.71		4.87	7.21	5.18	
1200	4.59	7.31	4.82		4.16	7.03	4.62		3.91	6.29	4.16	
1400	3.97	6.21	3.93		3.68	5.82	3.65		3.29	4.18	3.52	
1600	3.31	5.21	3.78		3.15	5.07	3.28		3.03	3.02	3.13	
Mean	4.42	7.45	5.15		4.15	7.07	4.90		3.97	5.99	4.49	
CD(0.05)	0.54	0.47	0.58		0.54	0.47	0.58		0.54	0.47	0.58	

*Relative abundance=number of foragers/5 min/m2, Foraging Rate=number of flowers visited/5 min, Foraging speed=time spent/flower (in seconds).

Table 2: Pollination efficiency Index of pollinators on watermelon

Sl. No.	Pollinator	RA	FR	FS	LPG	Pollination index
1.	*Tetragonula iridipennis*	4.43(3)*	7.45(3)*	5.15(1)*	1618(2)*	18.00
2.	*Apis mellifera*	4.15(2)*	7.09(2)*	4.90(2)*	2015(2)*	14.00
3.	*Tetragonula laeviceps*	3,97(1)*	0.49(1)*	4.49(3)*	1405(10*	5.00

*values in parenthesis are rank assigned.
RA=Relative Abundance, FR=Foraging Rate, FS=Foraging Speed, LPG=Loose pollen Grains.

Table 3: Impact of pollination on fruit quality and production in watermelon

Treatments	Fruit set (%)	Healthy fruit (%)	Deformed fruit (%)	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (kg)	TSS (%)	Rind thickness (cm)	Weight of 100 seeds (g)	Number of seeds
T1	53.55	65.58	11.89	20.6	17.3	2.38	9.3	1.7	6.29	156
T2	38.86	52.8	14.67	16.2	12.4	1.29	7.6	1.3	3.62	84
T3	53.37	63.18	11.51	19.5	15.3	2.19	9.3	1.6	6.01	140
T4	40.84	58.6	13.51	17.8	13.5	1.51	8.0	1.1	5.71	111
T5	44.72	60.18	13.08	18.3	14.7	1.68	8.4	1.3	5.84	127
T6	48.51	60.73	12.47	18.6	15.2	1.87	9.1	1.5	5.93	135
T7	35.84	49.68	16.52	13.0	10.5	0.95	7.1	1.1	3.08	70

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